Cloud Optical Thickness over Land Retrieval Problem in Collection 005

Version 1.0

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Summary

A retreival code problem has been identified in the Collection 005 MODIS standard cloud optical thickness Science Data Set (SDS) for cloud-over-land scenes (Level-2 (L2) SDS name *Cloud_Optical_Thickness*). The resulting error is thereby also noticeable to varying extent in SDSs dependent on, or derived from this optical thickness retrieval, including their aggregations in the Level-3 (L3) product. The other L2 SDSs affected are *Cloud_Effective_Radius*, *Cloud_Water_Path*, and related QA flags; likewise, the L3 aggregations of these SDSs can be affected, including their phase-dependent aggregation via the L2 *Cloud_Phase_Optical_Properties* SDS. Similarly, the L3 cloud fraction aggregation (e.g., *Cloud_Fraction_Liquid*, *Cloud_Fraction_Ice*, etc.) is affected to the extent that successful retrievals were found to be reduced to a minor extent due to the code problem.

The problem, originally noticed in cloud optical thickness histograms for both water and ice clouds over snow/ice-free surfaces, is manifest as a reduction in histogram counts for clouds with optical thicknesses of ~11 for water clouds and ~8 for ice clouds (e.g., Fig. 1). The primary problem was tracked to a coding error in the cloud flux asymptotic formula used in the Rayleigh correction routine (which is implemented only over snow/ice free land surfaces).

This document describes the problem and its fix (which began with the September 2007 forward processing stream). The extent to which the problem impacted global L3 statistics, including monthly means, is also presented.

Effected Science Data Sets (SDSs) and Time Period

This problem is found only in snow/ice-free land retrievals of cloud optical property parameters (cloud optical thickness, cloud effective radius, cloud water path, cloud fraction, and some QA flags) in L2 Cloud (06_L2) HDF files that cover the data period from launch through August 2007 (PGE 06 v5.11.0). Also impacted is cloud optical property derived data in L2 Joint Atmosphere (ATML2), L3 Daily (08_D3), L3 Eight Day (08_E3), and L3 Monthly (08_M3) HDF files for the same time period. Starting in September 2007, a fix was implemented into the operational production software which corrected this issue (PGE 06 v5.12.4). Starting with September 2007 data, the problem is eliminated in both L2 and L3 cloud optical property data.

History

This problem was first brought to the cloud optical property development team's attention by a MODIS data user who noticed a reduction or "dip" in counts for moderate liquid water cloud optical thickness (Tau) in histograms in northern Canada.

This dip was studied by Paul Hubanks (MODIS Atmosphere L3 developer) and was determined to exist globally over snow/free land areas and was impacting most strongly the Tau ~ 11.5 bin for liquid water clouds (Fig. 1). Some impact on ice clouds was also believed to exist, although the impact there was much smaller.

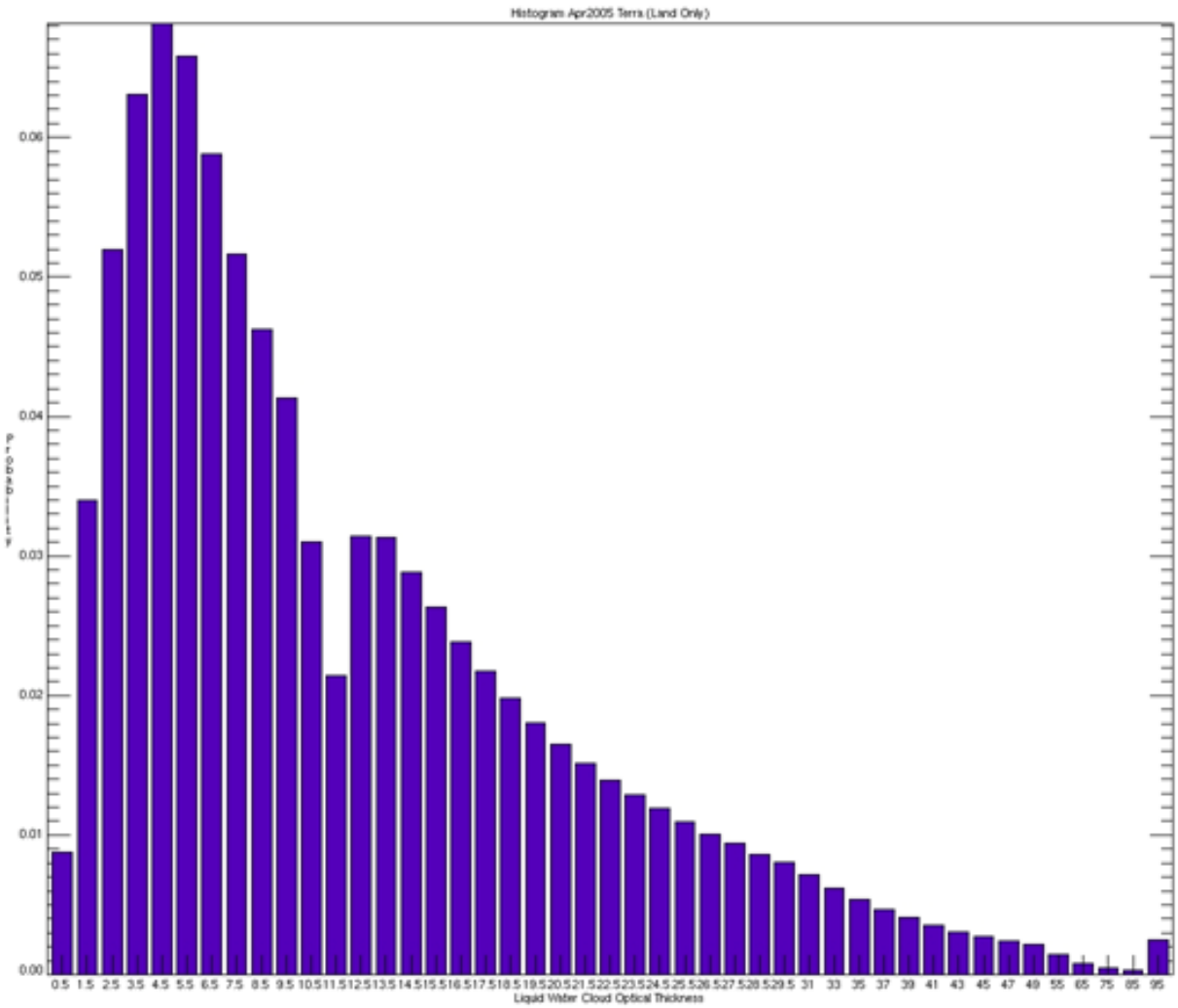

Figure 1. Monthly (April 2005 Terra) Histogram of Liquid Water Cloud Optical Thickness for Global: Land (snow/ice free & covered)

Diagnosis

The first step in the investigation was to determine where the dip in counts was maximized. Fig. 2 shows the ratio of the mean value of counts in the 11<Tau<12 bin divided by the mean of the 10<Tau<11 bin and the 12<Tau<13 bin counts. In short, it shows where the dip in counts for the 11<Tau<12 bin is maximized (the lower the ratio, the larger the dip in counts). Clearly this retrieval over land effect appeared to have a maximum effect over tropical regions.

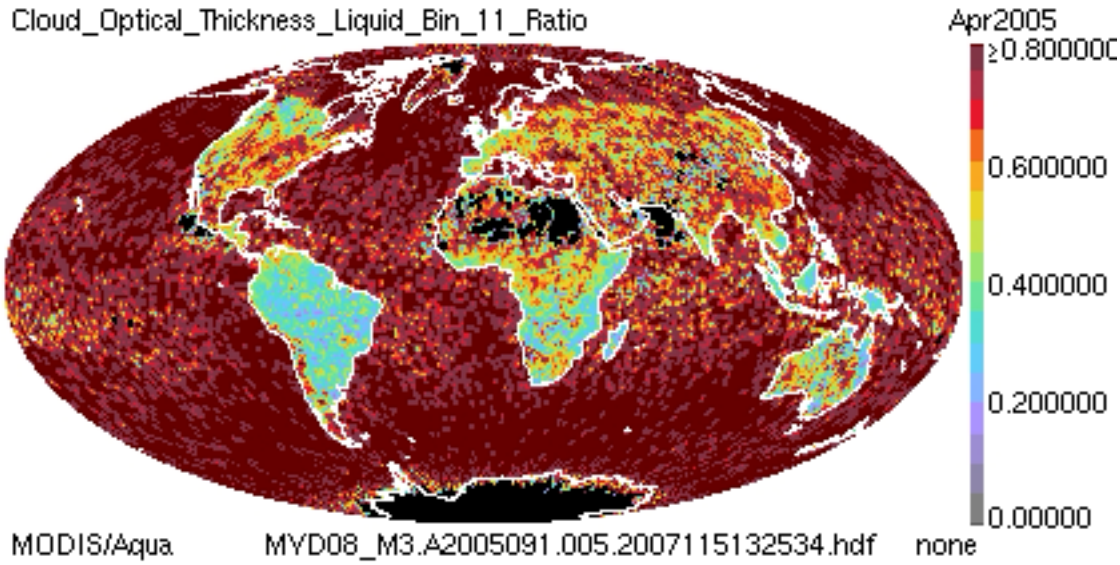

Figure 2. Monthly (April 2005 Terra) Image showing the magnitude of the reduction of counts for the Tau = 11.5 bin.

Hubanks traced the problem back to L2 data at which point Gala Wind (L2 Cloud Optical Properites developer) took over the diagnosis. Wind confirmed a dip in counts for liquid water clouds at Tau ~ 11.5 in the L2 data over land (Figure 3); and found a similar but smaller impact over land for ice clouds at Tau ~8.5 (Fig. 4). It should be noted that the red line shows the histogram from a Cloud HDF file computed from the problematic version of the cloud optical properties algorithm used to create Collection 005 data from launch through August 2007 (PGE 06 v5.11.0); the black line shows data from the same granule using a corrected version of the code (put into operations starting with September 2007 data (PGE 06 v5.12.4).

Wind traced the problem to the Rayleigh correction portion of the L2 cloud retrieval code, which is applied only over snow/ice-free land scenes; therefore cloud retrievals over ocean and snow/ice surfaces are not impacted. The Rayleigh correction is stronger for lower altitude clouds and so, in general, exacerbated the problem for water clouds while reducing the impact for ice clouds.

Two problems were found. The primary problem was in the cloud flux asymptotic calculation formula coded into the Rayleigh correction routine for conservative scattering over non-black surfaces. Second, an incorrect angle (solar instead of sensor) was used to interpolate the non-asymptotic cloud flux in the angle dimension; this problem primarily impacted high-latitude retrievals. Unfortunately, every cloud optical thickness retrieval over snow/ice-free land for Collection 005 from launch through August 2007 is affected by these bugs. The extent to which the problem impacts global L3 mean statistics is discussed in the next section.

A smaller effect was also found for effective radius (r_e) whose retrieval is dependent to a some extent on optical thickness. A plot for liquid water clouds is shown in Fig. 5. It should be noted that about 500 new points were gained in the effective radius after the code was fixed (i.e., ~500 “failed” re retrievals occurred in the original code but had valid retrievals with the fixed code). Noteworthy was a marked drop in counts in the r_e=29 effective radius bin. Overall, there was a slight decrease in counts to the right and slight increase in counts to the left of the peak of counts that occurs around r_e=19.

Because, cloud water path is derived from the product of optical thickness and effective radius, this SDS is also impacted. Finally, the L3 successful cloud retrieval fraction (the optical properties SDS, not cloud fraction from the cloud mask product) is impacted to the extent that failed retrievals (as described above) reduce the retrieval fraction.

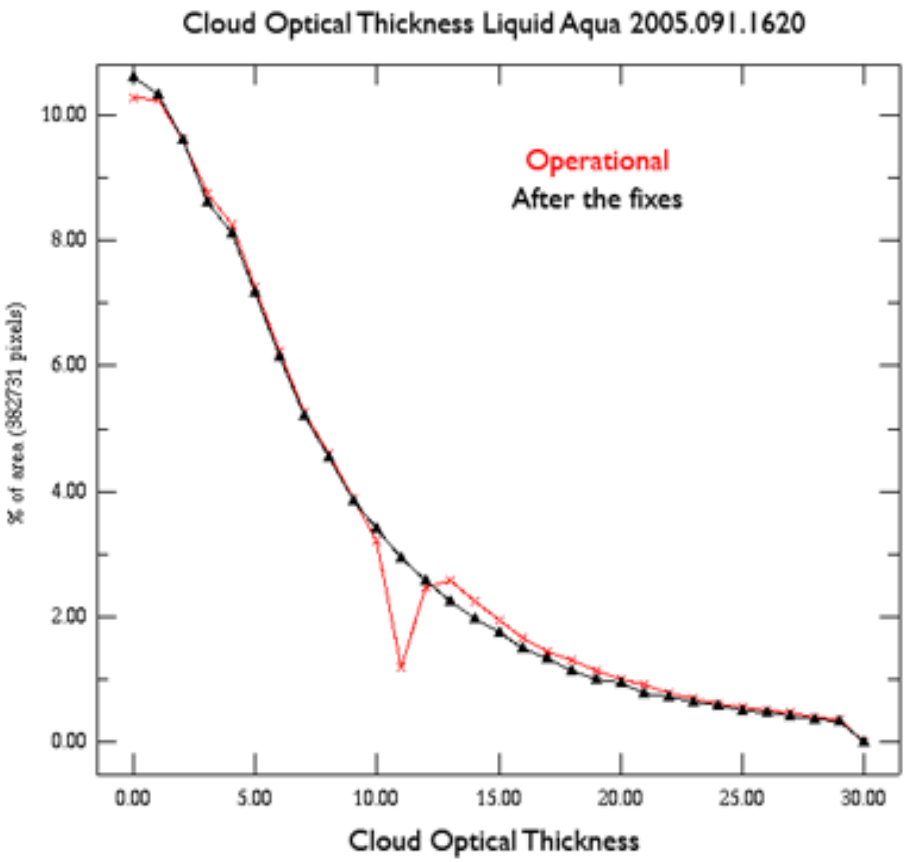

Figure 3. A histogram of Liquid Water Cloud Optical Thickness for a single L2 Aqua granule over the Amazon. Red=Originally delivered Collection 005 code (PGE 06 v5.11.0). Black=Corrected Collection 005 code (PGE 06 v5.12.4).

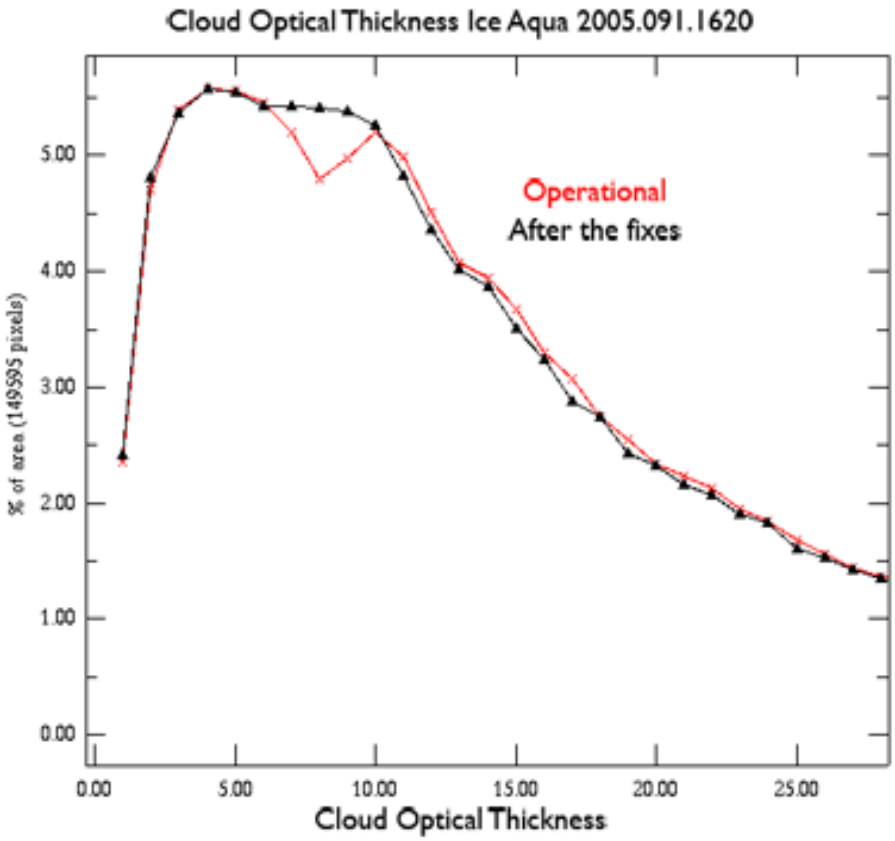

Figure 4. A histogram of Ice Cloud Optical Thickness for a single L2 Aqua granule over the Amazon.
Red=Originally delivered Collection 005 code (PGE 06 v5.11.0); Black=Corrected Collection 005 code (PGE 06 v5.12.4).

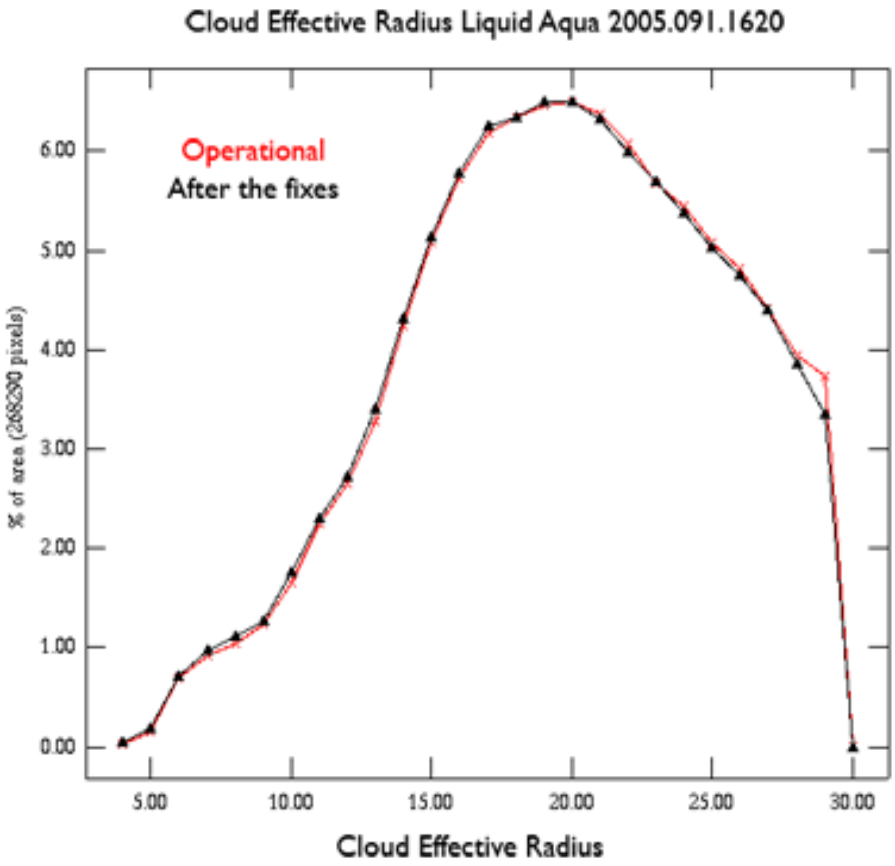

Figure 5. A histogram of Liquid Water Cloud Effective Radius for a single L2 Aqua granule over the Amazon. Red=Originally delivered Collection 005 code (PGE 06 v5.11.0). Black=Corrected Collection 005 code (PGE 06 v5.12.4).

Level-3 (L3) Impact

For L3, cloud optical thickness, and to a smaller extent cloud effective radius, statistics are impacted over snow/ice-free land. As mentioned, all cloud water path and cloud optical property retrieval cloud fraction statistics are also impacted. In L3, the problem is most noticable in the 1D (or marginal) histograms due to the existence of smaller bin sizes compared to 2D joint histograms (see Figs. 6 (original) and 7 (corrected) for example). However, there is some noticeable impact for Tau-r_e joint histograms (Figs. 8 (original) and 9 (corrected)).

Finally, we investigated the impact on global scalar statistics (mean and standard deviation) which is of primary interest to many users. Some minor impact was noted. In the monthly L3 mean statistic, the impact of the code errors is between 0 and +1.0 for water cloud optical thickness (i.e., positive bias) and about 0 to +0.2 for ice clouds. A much smaller impact was found in the water cloud effective radius means with a bias of less than +0.2 µm for most land surfaces though with a negative bias up to about -0.5 µm over the brightest desert surface grid points (Figs. 10, 11, 12). For the daily L3, the impact on the mean statistic is only very slightly larger with a typical error bias of about 0 to -1.5 or so (Figs. 13, 14, 15). Note that for these final six figures, the gray color shows regions where cloud data was missing (clear sky or orbital gaps).

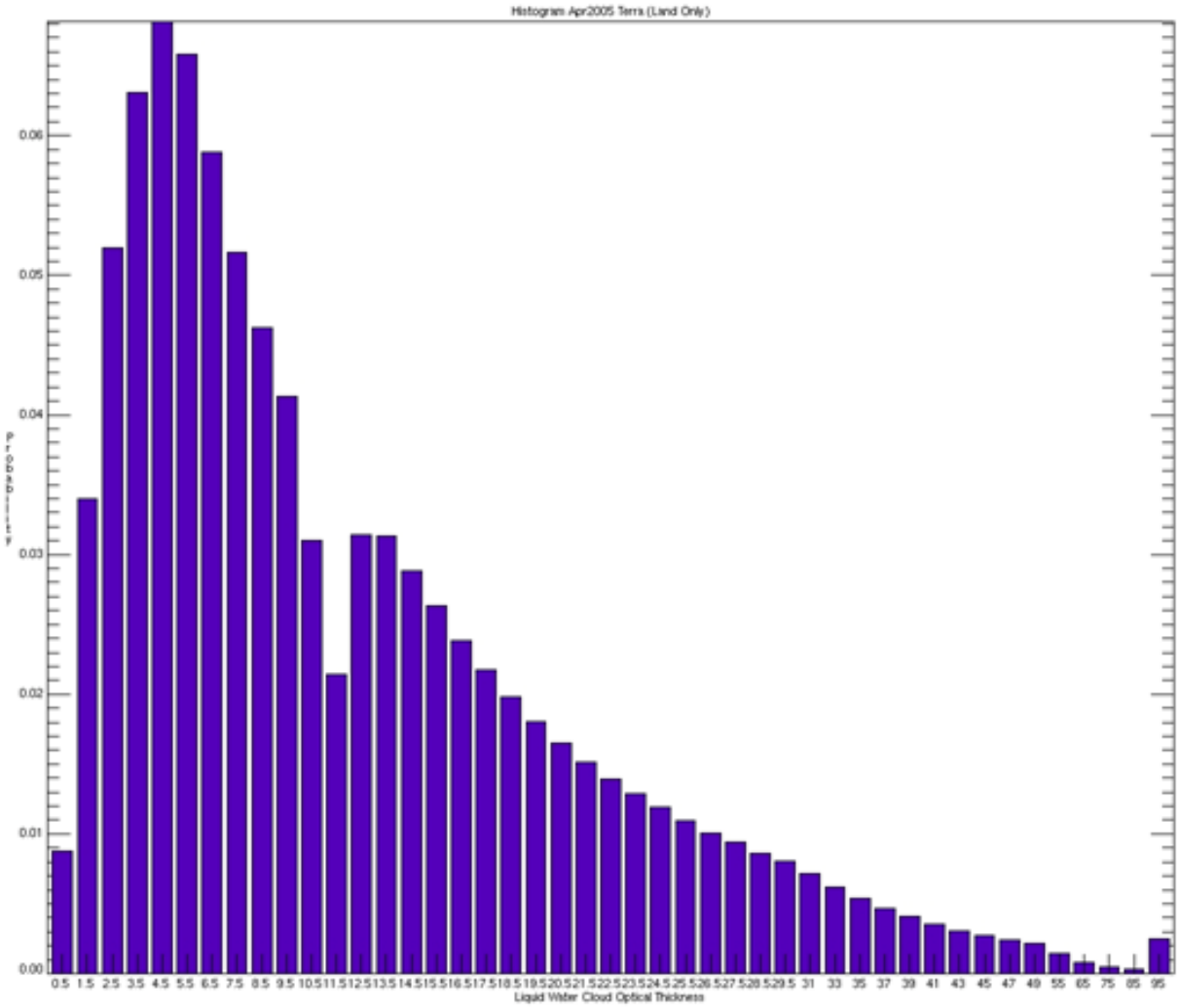

Figure 6. Histogram of Liquid Water Cloud Optical Thickness for April 2005 Terra over Land (snow/ice free & covered) **(original version)** (L3 data computed from L2 data from originally delivered Collection 005 code (PGE 06 v5.11.0)).

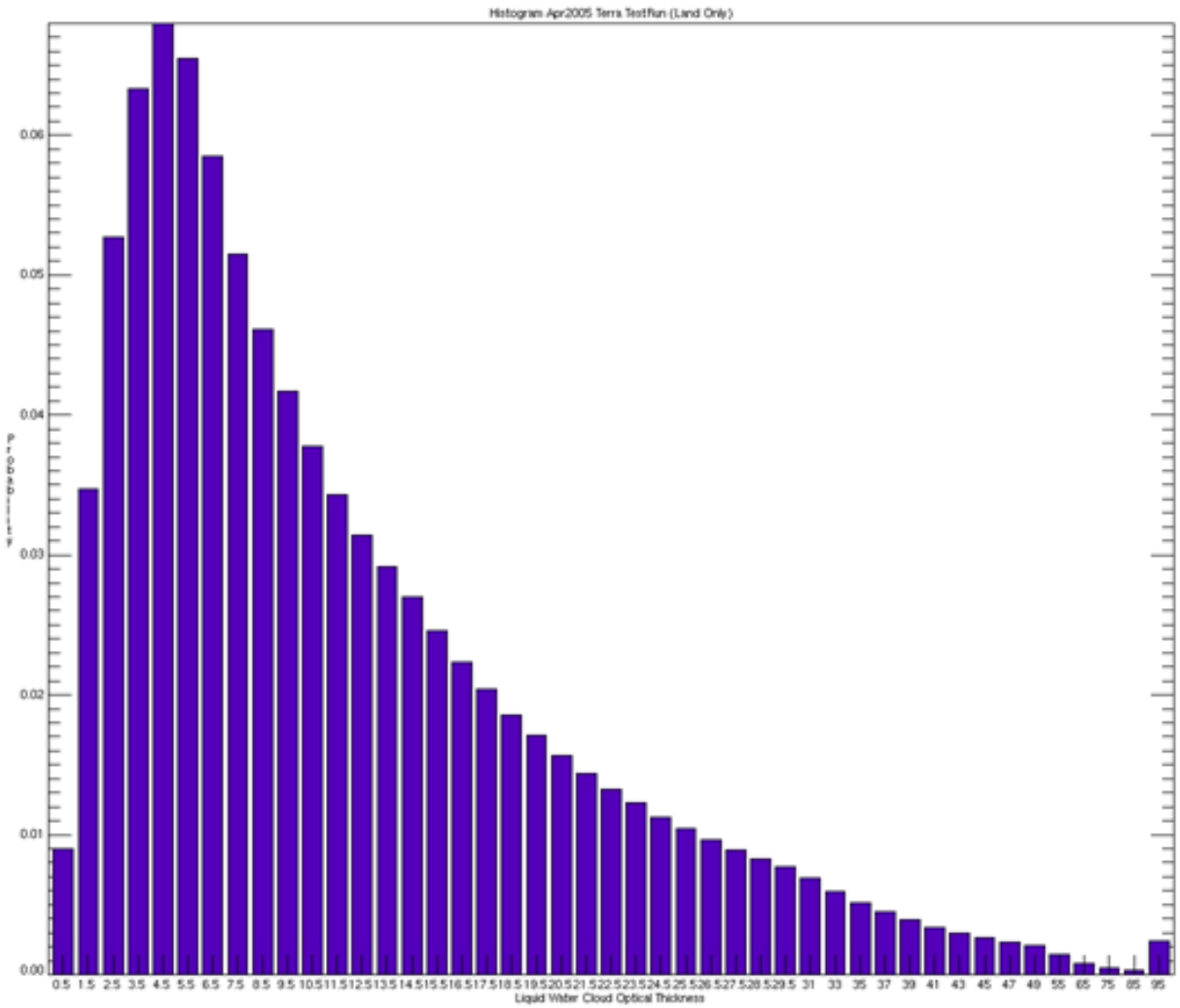

Figure 7. Histogram of Liquid Water Cloud Optical Thickness for April 2005 Terra over Land (snow/ice free & covered) **(corrected version)** (L3 data computed from L2 data from corrected Collection 005 code (PGE 06 v5.12.4)).

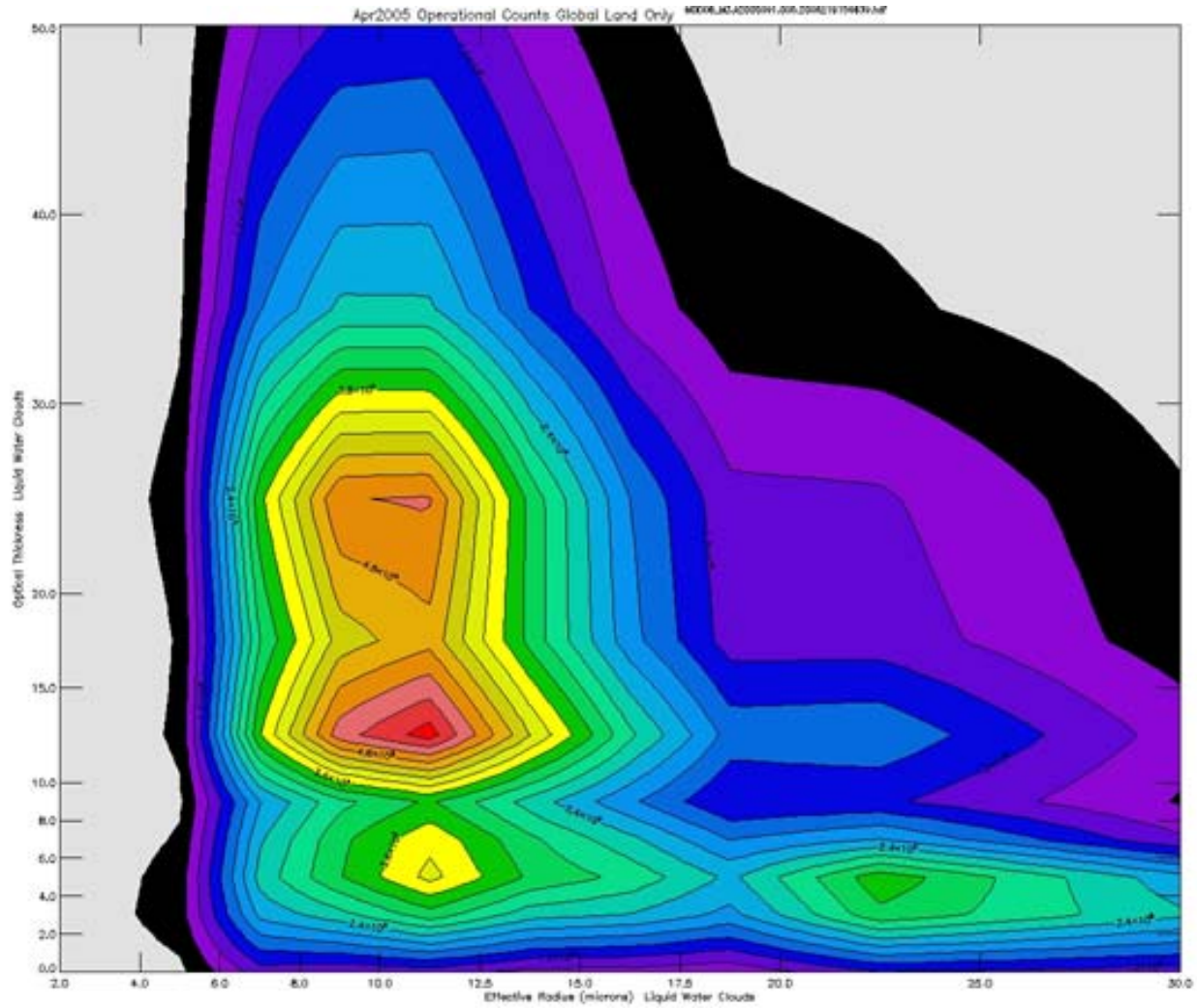

Figure 8. Joint Histogram of Liquid Water Cloud Optical Thickness vs Effective Radius for April 2005 Terra over Land (snow/ice free & covered) **(original)** (L3 data computed from L2 data from original Collection 005 code (PGE 06 v5.11.0)).

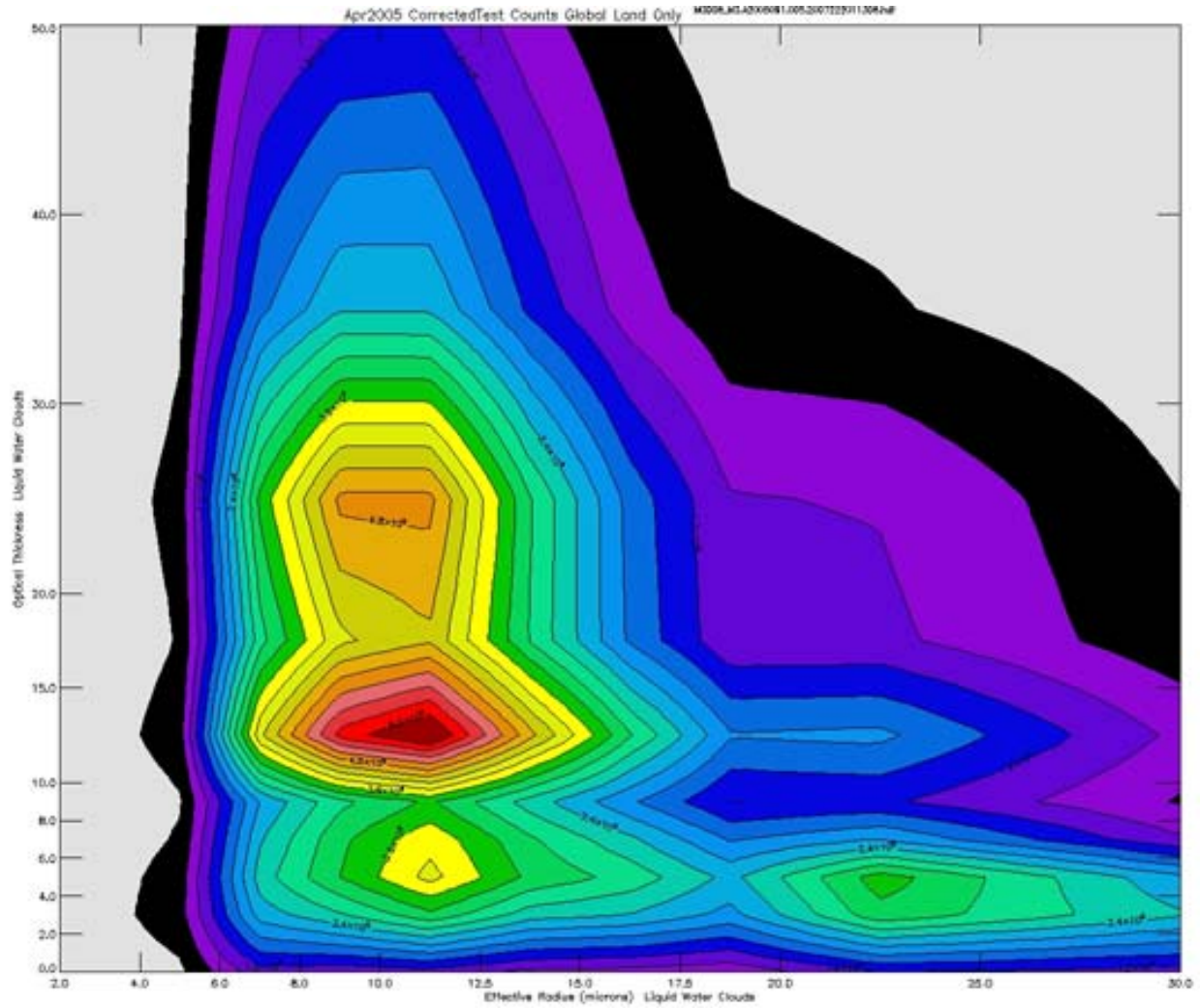

Figure 9. Joint Histogram of Liquid Water Cloud Optical Thickness vs Effective Radius for April 2005 Terra over Land (snow/ice free & covered) **(corrected)** (L3 data computed from L2 data from corrected Collection 005 code (PGE 06 v5.12.4)).

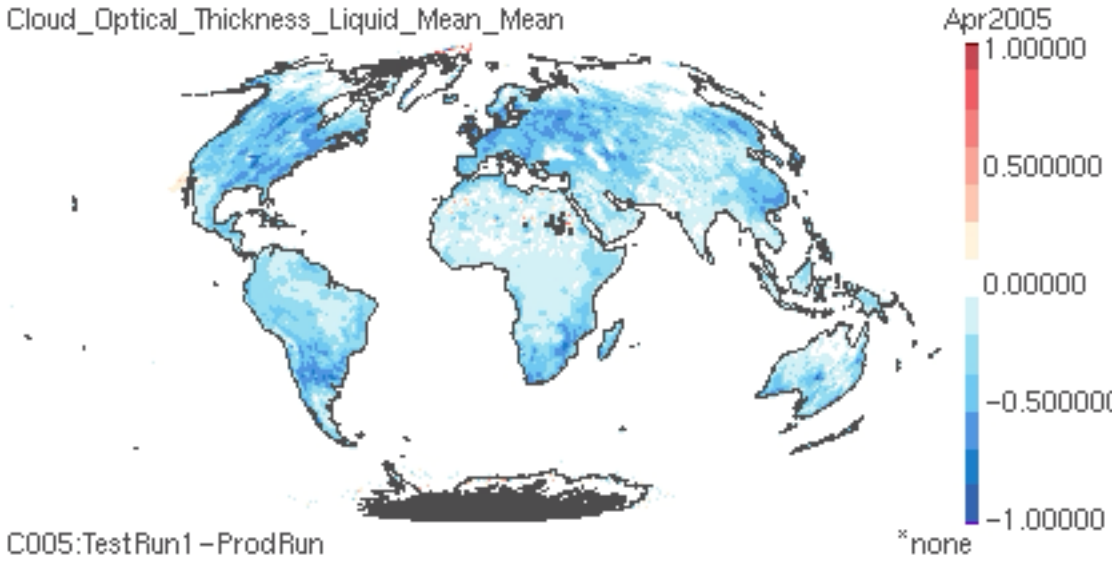

Figure 10. L3 Monthly Liquid Water Cloud Optical Thickness Mean Statistic difference **(corrected version – operational version)** April 2005 Terra.

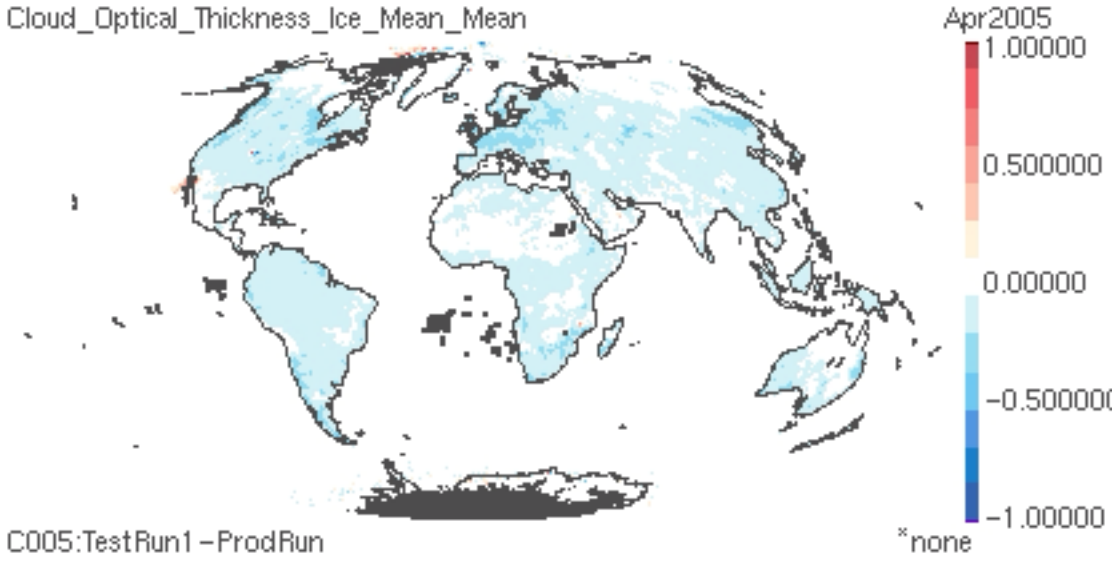

Figure 11. L3 Monthly Ice Cloud Optical Thickness Mean Statistic difference **(corrected version – operational version)** April 2005 Terra.

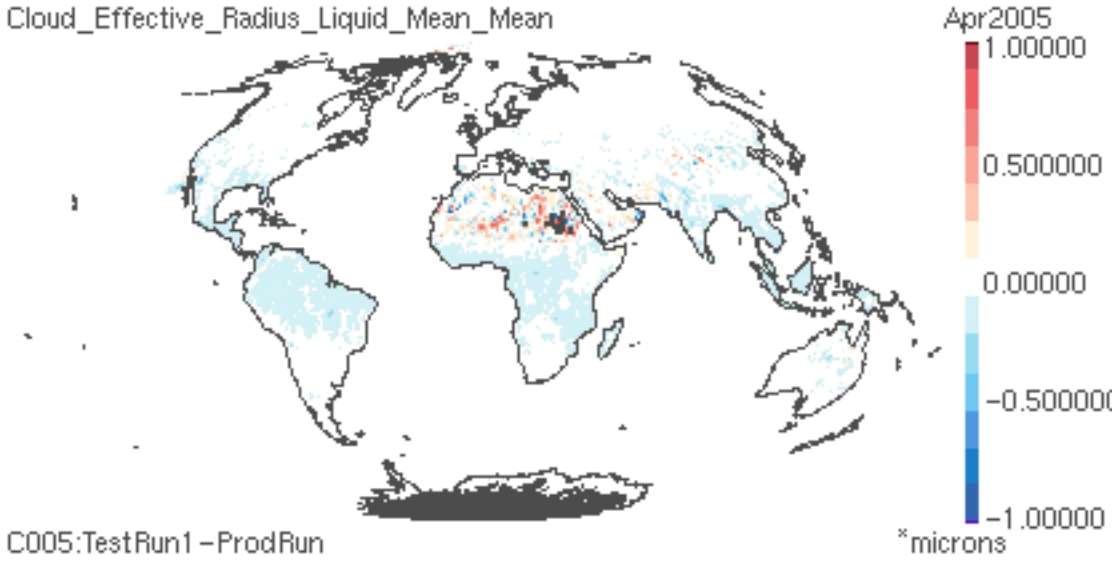

Figure 12. L3 Monthly Liquid Water Cloud Effective Radius Mean Statistic difference **(corrected version – operational version)** April 2005 Terra.

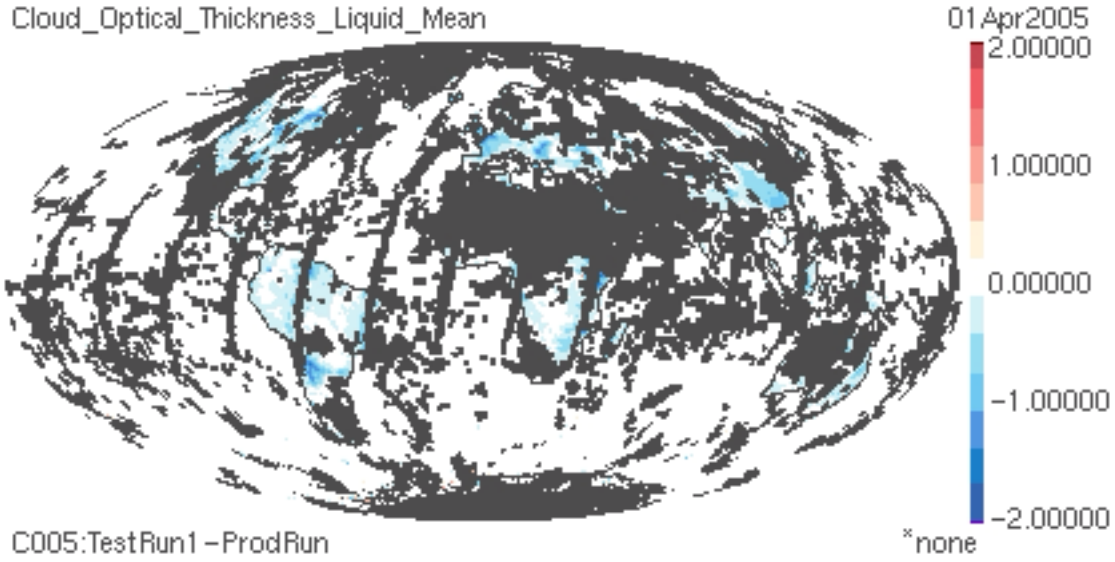

Figure 13. L3 Daily Liquid Water Cloud Optical Thickness Mean Statistic difference **(corrected version – operational version)** 1 April 2005 Terra.

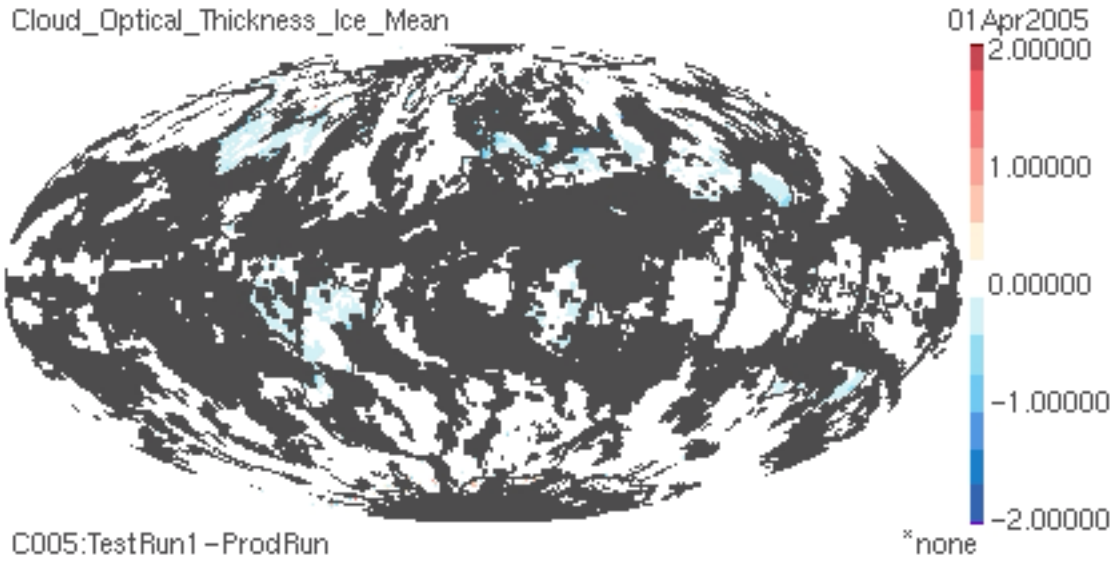

Figure 14. L3 Daily Ice Cloud Optical Thickness Mean Statistic difference **(corrected version – operational version)** 1 April 2005 Terra.

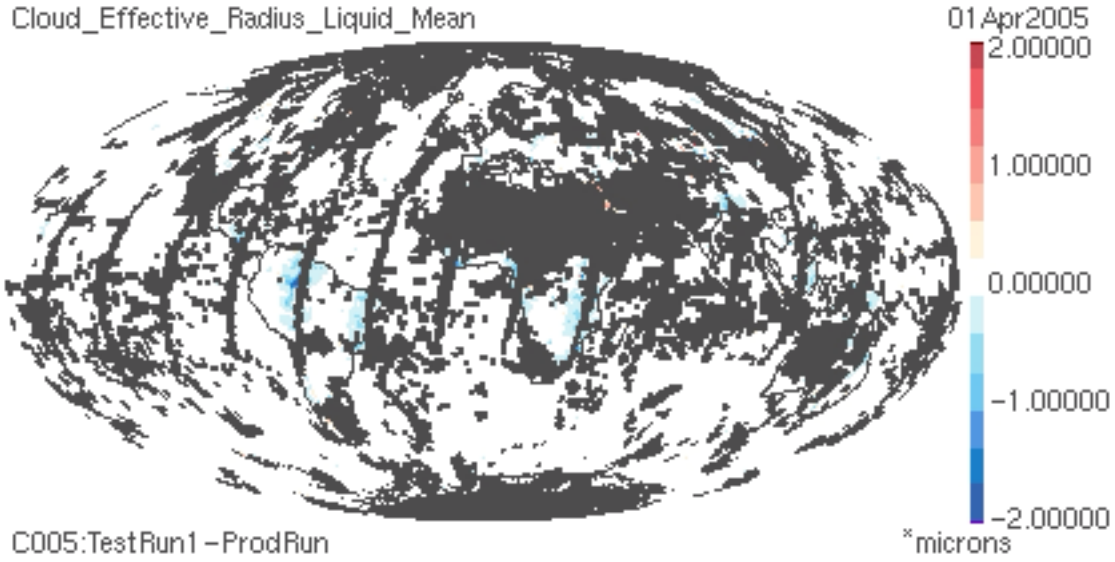

Figure 15. L3 Daily Liquid Water Cloud Effective Radius Mean Statistic difference **(corrected version – operational version)** 1 April 2005 Terra.